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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

AUTOMATED CONTROL SYSTEMS FOR INDUSTRY

Moscow IZVESTIYA in Russian 22 Apr 77 p 2

[Article by G. Kezling, General Director of the Leningrad Scientific Production Association Lenelektronmash: "Who Should Develop ASU?"]

[Text] A little over fifteen years have passed since the first automated control systems (ASU) appeared in our country. During this period significant practical experience has been amassed. In Leningrad alone during the Ninth Five Year Plan more than a hundred automated control systems were put into operation. And the effect of their introduction amounted to nearly 37 million rubles.

Yes, much has been done. But much more could have been done.

At the 25th Party Congress, General Secretary of the CPSU Central Committee, Comrade L. I. Brezhnev, formulated the primary task of the country's national economy--an all out increase in efficiency and quality. One of the instruments to achieve this is automated control systems. Meanwhile, the number of man-hours per job and the costs of its growth are still too great.

In previous years, we basically developed separate systems. And that was natural. The general principles and mechanisms were not yet clear. It was necessary to develop anew each successive ASU for every objective. Such "rediscovery of America" lead to excessive expenditures. The development cycle for a single system averaged 4 - 5 years, and the cost amounted to two million rubles.

But the requirements in automated systems continued to soar. It became clear that the earlier development techniques were no longer suitable. It was necessary to switch over to industrial line production methods and introduce automated systems. Expenditures for scientific research work needed to be reduced significantly by using standard designed solutions to the maximum, widely disseminating applied program kits, and learning to automate the

design of the basic ASU elements, particularly in the area of mathematical support, of which labor consumption and costs comprise 70 percent of the entire effort.

None the less, in recent years the number of organizations designing automated systems has increased. Amongst them are special purpose institutes and planning and design organizations, laboratories and ASU divisions in enterprises and in specialized institutes and design bureaus. And coupled with that in a series of ministries and departments they are striving to perform planning operations on the strength of second-rate organizations. For example, the ASU sector of the LenNIIkhimmash (Leningrad Scientific Research Institute for Chemical Machine Building) numbers 15 persons. The very same type of sector has been created in the Lengiproenergroprom (Leningrad State Institute for the Design and Planning of the Power Industry). There 23 specialists labor with an average annual work output of 13 thousand rubles. It is not difficult to imagine what kinds of systems and at what level they could be produced with such "strengths."

As a rule, such organizations are poorly equipped technically, and most importantly they stew in their own methodological "juice." Cases where specialists from these organizations are not even familiar with the materials which regulate ASU development, such as standard plans, algorithms and programs are not infrequent. It is no wonder that all this leads to the creation of systems based on yesterday's level of technology, without a hint of typification, disregarding the vast experience accumulated by the nation's leading collectives.

In Leningrad a regional interindustry system for the coordination of ASU development has been created and is successfully functioning under the direct guidance of the district party organization. It encompasses over 800 enterprises, organizations and educational institutions which have a bearing on the problem at hand. The coordination system, which was summoned to consolidate the efforts of scientists, specialists and economists, eliminates duplication and promotes a reduction of both the development cycles and costs for automated systems.

The interindustry coordination plan for the introduction of automated control systems became an integral part of a complex economic and social development plan for Leningrad and the Leningrad Oblast for the 1976-1980 period. In the process of developing the plan, the disproportion in expenditure distribution was eliminated and a preliminary saving of 50 million rubles was achieved.

Nevertheless, only large, powerful, and specialized organizations can solve the problem of creating the cheapest and most effective systems. One of

these enterprises, Lenelektronmash (Leningrad Electronic Machine Building), is the largest association in the nation's northwest and was created on the initiative of the Leningrad Obkom and the Ministry of Instrument Making.

Its staff numbers several thousand specialists and its Institute of Control Methods and Technology has a strong technical base. During the past Five Year Plan we succeeded in reducing the average development time for one system from four years to one and, taking into account all capital investments, brought the economic efficiency up to 46 kopecks for every ruble spent. In other words, in order for the system to fully pay for itself, it takes slightly more than two years. For comparison, let's say, the efficiency achieved by the small organizations is lower and fluctuates within very wide bounds--from six to 30 kopecks per ruble expended.

The time has come to turn from general discussions on this topic to specific actions and concentrate the entire development and introduction of automated control systems into the scope of the Ministry of Instrument Making.

With the advent of ASU, it is possible to apply this ideal technology and high-speed computers can be installed in regular plants. But if they are operated by unprepared and poorly qualified people, then the investment is wasted. Thus the scientific production association, Fosforit, acquired an expensive electronic computer, but uses it only two hours a day. Back in August 1975, the Lenenergro (Leningrad Electric Power) management purchased two sets of electronic computers; this technology has yet to be put into operation.

If they have just been supplied, computer service programmers and operators are obliged to undergo training, even if it is at a minimum level, though some enterprise managers, including even directors, as a rule, do not even trouble themselves with that. And as you know, it is only they, the managers, who can lay before ASU the enterprise's most pressing problems. But even the most experienced and talented director will be unable to cope with it without special and very well-grounded training.

In our view, the ministries and departments must create a branched network of regional interindustry institutes for raising skill levels in the areas of computer management technology and ASU, such as the Institute of Control Methods and Technology created within Lenelektronmash, and organize in the VUZ's and institutes in various cities throughout the country special courses for raising skills.

It is impossible not to say still more on the subject. Without question, automated control systems are indispensible. Nevertheless, there is no need to run to the opposite extreme. These systems are expensive and, so to speak, agressive tools which should be used with extreme caution.

Meanwhile, the general enthusiasm for automated systems has resulted in situations where they are created and used in places where they generally are not even needed. Not only is significant material damage inflicted on these enterprises, but faith in the efficiency of automation is undermined and the very concept of ASU is discredited. Just this very thing occurred at the Kolpino Sewing Factory. There they intentionally introduced an automated system unnecessary for production, even though it would have been more useful to simply improve the organization of the work and use little mechanization.

It seems that before deciding on the creation of an ASU, an enterprise is obliged to conduct a preliminary investigation itself to formulate an accurate technical and economic basis, because every time this question must be decided specifically depending on the nature of the production, the size of the enterprise, and a multitude of other conditions. And, of course, in spite of this one must proceed with clear cut criteria for the merits of ASU. Meanwhile, there is still no satisfactory procedure to evaluate the economic efficiency of automated systems.

The creation of powerful, specialized organizations, systematic training of ASU personnel, drawing up clear cut and precise efficiency criteria, and the rational use of computer technology are all necessary to solve the main problem placed before the national economy in the Tenth Five-Year Plan.

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CSO: 1870

AUTOMATIC CONTROL SYSTEMS IN TURKMEN CONSTRUCTION INDUSTRY

Ashkhabad TURKMENSKAYA ISKRA in Russian 27 Apr 77 p 2

[Article by correspondent G. Vasil'yeva: "Automatic Control Systems for Construction: The First Phase"]

[Text] People refer to the field of electronics as a young science and a science of young people. This is an accurate definition, and one becomes even more convinced that it is when he becomes acquainted with the operation of the computer-data center of the Ministry of Construction of the TSSR [Turkmen Soviet Socialist Republic], or IVTs Minstroy [computer-data center of the Ministry of Construction].

The computer center itself is young; it has been in operation since 1974. The people who work here are young, their age varying between 20 and 30 years. Electronics engineers are not the only ones who work here. Computer center personnel include construction people, economists, mathematicians, people who have mastered the specific problems of work in the area of control in the construction industry.

The computer center of Minstroy TSSR is an organization which has still not progressed beyond the growing stage. It still does not have its own location and has taken shelter in a basement which is rather crowded even for its small staff. There is so far one "Minsk-32" computer (one of the second generation) in operation, but it is expected that a second, more improved unit will be in operation in 1979 as part of a unified computer system.

Meanwhile, IVTs Minstroy TSSR is the smallest such operation in the system of the Ministry of Construction of the USSR. It is nevertheless far from operating at full capacity: while the main computer-data center of Minstroy SSSR [Ministry of Construction of the USSR] solves 30 complex problems, the computer center of Minstroy TSSR solves only 15, mainly for the ministry apparatus. In addition, the computer is in operation an average of only 12 hours a day, while it should be in operation at least 15 hours a day.

Computer personnel are now working on the introduction of an automated system for control of construction, which is now being referred to as ASUS.

The path to the accomplishment of this task runs through weekly planning and selection conferences organized by computer center personnel together with specialists of the Ministry of Communications of the TSSR; through the development of a schedule for deliveries of concrete to sites in the three cities of Krasnovodsk, Chardzhou and Ashkhabad. This very laborious, but most necessary, task, which has as its goal the coordination of the work of mortar-mixing centers, transport enterprises and construction sites, can be accomplished by the computer in 15-20 minutes (for each city separately), while the "manual" solution to the problems involved, even with the use of office machines, would occupy two specialists at least four hours a day.

The "Minsk-32: now assists in the development of plans for deliveries of a full assortment of reinforced concrete structures and in calculating the requirements of plants manufacturing these items for metal, cement and aggregates. If we consider that Minstroy TSSR is one of the country's largest users of prefabricated structures in construction (its use percentage exceeds 80), we can imagine how great and complex is this task. It is enough to point out that control personnel of "Turkmenstroykomplekt" and the "Turkmenstroyindustriya" trust no longer think of solving a whole series of problems without the use of the computer, especially problems involved in the supply of materials and equipment.

Computers assist in bookkeeping and accounting operations, in keeping records of the movement of material assets in warehouses for control of supplies to meet the technical-production equipment needs of "Turkmen-tsentrostroy", and a number of technical-economic planning and control problems for construction trusts are being introduced.

Everything mentioned so far comprises the first phase of an automated control system for construction, the introduction of which was completed in 1976. The final results of the second phase of Minstroy's ASUS will be a high level of administrative efficiency and effective discipline and organization of all planning and accounting operations.

"Our greatest concern," declared my host, the head of the center, V.A. Gasanov, "is the creation of standardized ASUS hardware and the instruction and training of personnel in subdivisions of Minstroy in ASU [automatic control system] operations. Without this, the 'Minsk-32' could not operate effectively."

The speaker had to be convinced of the truth of this, since my visit to the center coincided with the last days of March, when distribution to enterprises of the plan for deliveries of complete assortments of steel-reinforced concrete structures was being completed. But it was not ready in time. Why? It was not the computer's fault....

But we won't search out the guilty parties. Difficulties invariably accompany the introduction of innovations. Minstroy's computer center is going through such a period now. And how it is getting on...all is buoyed up by the enthusiasm of trailblazing pioneers, if as such one can refer to people who witness with their own eyes the transformation of a run-down basement into an area with a modern interior and the unpacking and setting up of electronic computer hardware inside.

Vyacheslav Stepanovich Chepelev became acquainted with computer hardware within the walls of "Orgtekhstroy". The "super" system being introduced by its specialists, which coordinates the operations of the mortar mixing center, motor transport and construction sites of Ashkhabad, still lies at the basis of the operations of this production sector in the "Turkmentsentrostroy" construction administration. And construction engineer V.S. Chepelev, one of the participants in the introduction of this system, has been "smitten" ever since with a permanent interest in an electronic computer technology which expands man's creative capabilities and conserves his energies.

This interest did not pass unnoticed. When the question arose of sending a person for training at the Moscow Engineering-Economic Institute imeni Ordzhonikidze, which had established an ASU department, one of the first to be named a candidate was V.S. Chepelev.

Chepelev was not the only one for whom at that time the "super" system served, in its own way, as a starting point. It also introduced A.V. Andreyev to electronics, and we see him now in the post of head of the division responsible for the introduction of ASU and new equipment in the technical administration of Minstroy; it played a similar role in the life of Yu. R. Voskanov, presently a group leader in the computer center's ASU division. Chepelev is deputy director of the center and plays an active role in the introduction of computers into the field of construction control.

I happened to meet one other enthusiast in the center's holy of holies, in a large room, a sign on whose door bore the stern warning "Unauthorized persons keep out." This was the computer room in which the "Minsk-32" was located.

The computer is not one piece of equipment, but rather a whole complex of units arranged in some sort of well-ordered disorder. Two rows of metal cabinets. "Here are the electronic memory units, over there the magnetic recording," said V.A. Gasanov, who was accompanying me on this tour. A control panel covered with many square knobs which blinked off and on with different-colored lights. The heavy air conditioner housing under the

ceiling. "If the air conditioner were to be turned off," V.A. Gasanov mentioned in passing, "within half an hour the temperature in the units would be almost 40 degrees rather than 20...." A printer over which bent two figures in white smocks.

One of them turned out to be the director of technical support, Lev Grigor'-yevich Griber. Vladimir Aliyevich Gasanov took some time before he decided to answer my question about what Griber was doing.

"You see, it's like this. Griber is one of those who devotes all his spare time to his work. You can see the practical truth of this in the fact that he watches after the computer during the day, and then, when necessary, at night as well."

"You really don't get tired?" This question I directed to Griber.

"Yes, but somehow I don't notice it," replied Lev Grigor'yevich, smiling. "Of course, one has to sleep and eat.... But this computer is incredibly interesting, and when I'm around it I don't notice how time flies...."

As a characteristic feature of the work of the computer center one can point to the collective approach to the operation. Not one of the people who work there can be considered the personal author of any development. But despite the fact that it is this sort of operation, you can still spot some especially enthusiastic people. With pleasure V.A. Gasanov named me the names of V. Teytel'baum, L. Gus'kova, the man-and-wife team of V. and L. Frizen, Ye. Biyenko, A. Safarova, N. Savina, L. Berman, S. Kasparova and many others.

So goes the life and work of one of the computer centers in the republic's capital. And there are more than a few of them in Ashkhabad. Vladimir Aliyevich counted about ten. As I mentioned earlier, the computer center of Minstroy TSSR has now introduced the first phase of its ASUS into operation. V.A. Gasanov told me about the problems surrounding the introduction of later phases.

The one which is of most vital importance is the problem of personnel and their training for work which requires a high level of precision. A computer's effectiveness is found to be directly dependent on the qualifications of those who work with it, beginning with the line personnel of the construction subdivisions and going all the way to those who program problems for the computer. Unfortunately, gaps and flaws are permitted to exist on all steps of this staircase which interfere with the productive operation of the ASU.

Still another problem is the construction of a building for the computer-data center. For the present time, a complex of problems and measures has been developed for the first phase of the ASUS. It is necessary now to proceed on to the second phase, which will call for the connection of another, higher-capacity computer, one of the "Ryad's," to the existing computer. This computer is scheduled to be delivered in 1979, but will a new building be built by this time? An area next to the ministry building has been allotted for it. The project is still in the development stage; it has still to be assured of the requisite material-technical and financial resources. Will the new computer have long to "languish" in its packing crates?

Another problem involves the lack of reliable communications with outlying areas. In this regard the problem presents itself of the creation of an independent computer-data center in Chardzhouskaya oblast, which during the Tenth Five-Year Plan (and promises during the next five-year plan) to become the scene of the largest construction sites in the republic: an oil refinery in Neftezavodsk, the expansion of the superphosphate plant in Chardzhou, a large industrial complex in Gaurdak, and a number of others.

All these problems urgently require attention today.

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

OPERATION AND USE OF MICROCALCULATORS

Moscow RADIO in Russian No 4, Apr 77 pp 26-28

[Article by G. Antonova, Ye. Kuznetsov and L. Minkin :"Microcalculators"]

[Text] In recent years, one of the dominant trends in the design of radio-electronic equipment has been its miniaturization. In so doing, significant consideration is given to the integration of functionally completed components of the equipment.

Improvements achieved by microelectronics in the area of developing and putting into industrial production large scale integrated (LSI) circuits with a high degree of integration--as many as 20,000 transistors in the area of a 15-25 mm^2 chip--have permitted the creation of both logic and memory units on a single chip without which electronic calculators would be unthinkable. With the advent of LSI circuits, the creation of pocket calculators became a reality--microcalculators, the largest mass production item of today's microelectronics.

Microcalculators being produced by our industry can be divided into three groups: those for simple, engineering and scientific-technical computations (programmable). Microcalculators for simple computations differ from the others by a limited capacity for execute functions (usually the four arithmetic operations), minimum size and low cost. They are designed for the mass consumer.

Microcalculators for engineering and scientific-technical computations feature a broadened capacity for performed functions, the capability to be programmed and, naturally, the highest cost.

The basis for all microcalculators is the LSI circuit (see figure 1) which is made in the form of a semiconductive chip measuring 5X5.2 mm, where the various microcircuit elements are formed and combined with each other by successive technical operations.

The current rapidly progressing MDP (metal-dielectric-semiconductor) technology is the most suitable technological base for the manufacture of LSI

circuits for calculators, and specifically the varieties known as p-channel MDP technology and complementary structure technology (DMDP). The first of these is applied primarily in the making of LSI circuits which are used in externally powered microcalculators; the second is for calculators with an autonomous power pack.

More promising is DMDP technology. The microcircuits made for it are characterized by very low power input (1 microwatt/rectifier), relatively fast response (to 1 Mhz), wide ranging power pack voltage (from 3 to 15 Volts), and good congruence with the liquid crystal displays.

Regardless of its functional purpose, for the automatic execution of computations in any microcalculator it is necessary to provide numerical and command input information, store it for a period of time, execute specific operations in accordance with the computations' given algorithm, and output the result on the display device. A keyboard device I, LSI circuits II, display III, and a power source IV accomplish all the enumerated functions (figure 2 depicts an enlarged structural diagram of a microcalculator regardless of its purpose).

As has already been pointed out, the bases of a calculator are the LSI circuits which consist of a data input 1 and output 7 device, storage units (memory) for both operational 2 and permanent functions 3, a control device 4, an arithmetic-logic device 5, and a base frequency oscillator 6. Before proceeding to a discussion of how a microcalculator works, we shall examine the designations of the separate LSI circuit modules.

The input unit is necessary for congruence of the keying device which comprises a commutation field (matrix) with switches (keys) and LSI circuits, and for input into its numerical and command information. The output unit controls the work of the display--a multidigit numerical signal panel.

The permanent memory unit is the nucleus of the LSI circuit. Stored in it are microprograms by which are executed all the computational functions (addition, subtraction, division, multiplication, sine-cosine calculation, etc.) and operational functions (input of data and commands, output of the computational results, overflow analysis, protection against contact "jamming" and pressing two keys simultaneously, etc.).

The operational memory is necessary for storing the numbers involved in the computation, and also interim results and constants. Addition, subtraction and number correlation (in binary or decimal form) emanate from the arithmetic-logic unit. The control unit activates the signal sequence which controls the separate LSI circuit modules. The flip-flop devices (they are called "flags"), which are a part of this unit, change the microoperations' execute sequence.

In order for all the elements of the microcalculator to work as a single, coordinated mechanism, there is in the LSI circuit a base frequency oscillator which produces the synchronization and phase signals.

And now let's examine how a microcalculator works. Its work may be considered in terms of a given series of operations, taking place both within and without. Such operations are, for example, data input from a keyboard, execution of operations in the arithmetic-logic unit, display control, and so forth.

Everything begins with the activation of the power. With the introduction of power, a special flip flop prepares the fixed memory unit for the output of the microcommands.

Within 100-500 ms the first microcommand from the microprogram, "Initial Condition Setting," is fed from it into the control unit. The end result of this microprogram is the preparation of the operational memory for work (it is ready to receive information), and the control unit flip-flops are set in the specified condition. Then the microcalculator proceeds to execute the next microprogram. The information output from the operational memory unit occurs on the display and the keying unit interrogator (without a single key having been touched). This microcommand is periodically repeated. Until the operator performs a computation, only the zero and decimal point will light up on the display, indicating that the microcalculator is ready to work.

Upon pressing any of the microcalculator's keys, the appropriate input and output circuits of the keying unit matrix are connected, and in the control unit one of the flip-flops "flags" is set at the unitary condition, thereby registering the pressing of the key. Following the next iteration of the microcommand's interrogation of the keying unit, the execution of a new microcommand, "Protection Against Mechanical 'Jamming'," is begun. Its purpose is to inhibit the initiation of the next microprogram, "Input and Recognition of the Pressed Key," for 15-30 ms (depending on the keyboard type). This circumvents malfunctions in a rhythmically working unit. Depending on the pressed key (after a designated time interval), either the input of a number and its coding, or the execution of a function (computational or operational) takes place. Each pressed key conforms to its rigidly specific microprogram which is kept in the microcalculator's fixed memory.

The first number participating in the arithmetic operations (addition, subtraction, multiplication and division) is input in sequence from the keyboard--digit by digit. It is placed in the operational memory, and then upon interrogation is reflected on the display. After that the operator specifies what is necessary to be done with this number, that is which function must be computed. This command is memorized, and the operational memory unit is readied to receive the next number. It is input in much the same way as the first, stored and lit up on the display. Upon pressing the "Execute" key (the symbol = is usually inscribed on it), a microprogram, conforming to the earlier pressed key, proceeds from the fixed memory unit to the microcalculator's modules. Computation of the function assigned by the operator takes place in the arithmetic-logic unit. The result of the computations enters the operational memory and is reflected on the display. The first number is "erased" from the memory. The calculator is ready for further work.

Computations of trigonometric, logarithmic and similar functions are derived with the aid of special microprograms stored in the fixed memory unit. Results of the interim operations are stored in the operational memory and are not output to the display. Only the final result of the computations is entered on it.

The first domestic microcalculator was the "Elektronika BZ-04" with four DMDP LSI circuits. A liquid crystal display was used for reflecting the information. One could perform only the simple mathematical calculations (addition, subtraction, multiplication and division) on this microcalculator.

Today, there have been developed several microcalculators designed for both simple and complex, engineering computations--the "Elektronika BZ-18A," "Elektronika BZ-18M," "Elektronika BZ-26," and "Elektronika BZ-26M." All of the listed microcalculator models were made with a single LSI circuit, which contains from six to ten thousand elements. These microcalculators work from both autonomous and line power supplies. Vacuum-luminescent displays and light diodes are used for displaying information. Data and command input are accomplished with the assistance of a built in, key-activated panel.

The "Elektronika BZ-18A" and "Elektronika BZ-18M" microcalculators belong to the so called engineering computing units. They are designed for mathematical calculations using the four arithmetic functions over a range of real numbers from 10^{-7} to 10^{8}-1. The particular models employ a 20-key panel. Pressing the keys in sequence, they give an instruction as to which action is to be performed with which numbers, and then having pressed the button with the "=" symbol, the result is received almost instantaneously. Besides the arithmetic functions, the "Elektronika BZ-18A" and "Elektronika BZ-18M" are able to instantaneously extract square root, square numbers, compute natural and common logarithms and trigonometric functions (direct and inverse), and raise numbers to a power. Thus, for example, for the computation of the sine of an angle, the microcalculator with its own internal program carries out tens of arithmetic operations by the famous Taylor expansion. At the same time, the magnitude of the angle can be given both in degrees and in radians, for which a small switch is provided on the front panel.

Microcalculators can compute the functions listed above with an accuracy of ± 1 to the sixth place of the result. Monitoring of the input of the source data and computational results is accomplished visually with the aid of an eight-digit vacuum-luminescent display. A ninth function position is provided for displaying the sign of a negative number and the indications of word length overflow. The internal memory of the microcalculator broadens its feasilility and facilitates the solution of complex problems.

The overall dimensions of the "Elektronika BZ-18A" and "Elektronika BZ-18M" microcalculators are 160X90X40 mm, and the mass is 400 g. The D-0.55S storage batteries provide at least three hours of autonomous work. Four elements of the A-316 may be used as the power source for the "Elektronika BZ-18M" microcalculator.

The "Elektronika BZ-26" microcalculator differs from the microcalculators developed earlier in the USSR by its technical characteristics, modern design solutions, low power consumption, and ease of operation. The low power consumption is governed by the use of LSI circuits, the output of which is connected up to a light diode display without a matching unit (driver).

The "Elektronika BZ-26" microcalculator is also designed for executing mathematical calculations using the four arithmetic operations, figuring percentages, extracting square root, and it can accumulate and store date and computational results. The number display range is from 10^{-7} to $10^{8}-1$. The accuracy of the computations is to eight places. The overall dimensions of the "Elektronika BZ-26" are approximately 152X74X22 mm, and the mass is 300 g. The autonomous operation time using the A-316 elements is 7-10 hours.

The "Elektronika BZ-26K" microcalculator, called "Commercial," is designed for economists, accountants, and cashiers. The distinction between this model and the "Elektronika BZ-26" is that it has specific supplementary keys, "Payment," "Payment on Account," and "Change," and it permits computations of surcharges and discounts. The keyboard consists of 23 keys. The housing design, overall dimensions and power elements are the very same as those of the foregoing "Elektronika BZ-26" model.

The advantages of all microcalculators are their fast operation, precisional accuracy in computational execution, small size and weight, low power demand high reliability, relatively low cost, and, no less important, ease of operation.

Microcalculators are affecting our lives on an ever widening scale, lightening the labor of scientific workers and engineers, economists and accountants. Each year the output of microcalculators will increase, and the needs of the national economy and the broad masses of the population will be completely satisfied.

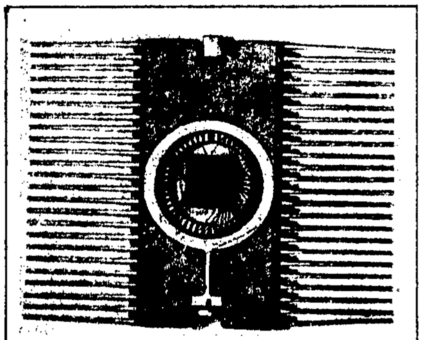

Рис. 1

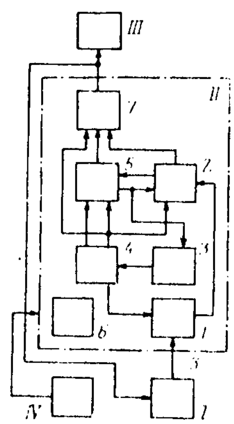

Рис. 2

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WORK OF ARMENIAN INSTITUTE ON UNIFIED COMPUTER SYSTEM

Yerevan PROMYSHLENNOST' ARMENII in Russian No 3, 1977 pp 24-27

[Article by correspondent P. Svetlanova]

[Text] First acquaintance with the new electronic computer created at the Yerevan Scientific Research Institute of Mathematical Machines (YerNIIMM) occurred in Moscow. In 1973 the ES-EVM-73 exhibit was opened at the Exhibition of Achievements of the USSR National Economy and aroused much interest in Soviet and foreign specialists. This was the first exhibition of computer machinery and equipment created jointly by CEMA partner-countries. The presented six new electronic computers and 120 units of peripheral equipment were developed according to a single plan and in a complex formed the Unified Computer System (UCS). This was the result of several years of work in the area of the creation of third-generation computer equipment, made according to a unified design and technological basis, jointly programed in a machine language.

The ES-1030 computer, developed by a collective of authors of the YerNIIMM, occupies a special place in the UCS. Its capacity is rather large -- 100,000 operations per second (let us recall, for comparison, that the ES-1010, developed in the Hungarian People's Republic, counts with a speed of 10,000 operations per second, the ES-1020 (the USSR and the People's Republic of Bulgaria) worked at a rate of 20,000 operations), which it makes it possible to use the machine to solve a wide range of problems. Of all the ES models it has the greatest capacity and can be effectively used in large computer centers and complex automatic control systems.

The exhibit at the Exhibition was the first important success -- the author's collective of developers and the production workers who had carried out the introduction were awarded gold, silver and bronze medals. Subsequent demonstrations at international fairs at Brno and Poznan have brought international recognition. The machine also won gold awards there.

The success was by no means an accident, but was a natural result of several years of intense research of a large group of investigators.

The assurance of compatibility of the Yerevan computer with other ES models was developed under the supervision of A. T. Kuchukyan.

Theoretical research on the selection of the computer structure was supervised by L. Kh. Gasparyan (on the right in the photo); input and output devices were under the supervision of G. O. Patvakanyan.

A. A. Narinyan supervised the creation of the basic design.

"The development and creation of electronic computers is an area in which collective creativity is necessary," says Corresponding Member of the Academy of Sciences Armenian SSR F. T. Sarkisyan, "the creativity of people on the leading edge of science, for lagging behind the times here is literally similar to death. We have no right to 're-invent the bicycle'"!

The scientific and technical potential of the institute is high enough for the developments created there to be on the level of the times. "Nairi" computers have formed an entire stage in the development of Soviet production of computers. The group of associates who developed the "Nairi-3" third-generation computer was awarded a State Prize USSR. Work on the "Nairi" model was continued and preparations were made for the creation of a fourth-generation model. Simultaneously in the institute a new section was formed with the task of creating another machine, called the ES-1030. The development of the younger sister of the "Nairi" was entrusted to Candidate of Technical Sciences M. A. Semerdzhyan.

"In an epoch of rapid development of technology it is very difficult to create a machine on the contemporary level," says Candidate of Technical Sciences L. Kh. Gasparyan, deputy chief designer of the ES-1030. "Mathematicians, electronic specialists, logicians and designers have been taken on for the work -- they are all studying the structure of the machine. The work has been

The planning of modern computers is impossible without drawing in computer technology. Candidates of Technical Science I. B. Mkrtumyan (on the left) and A. B. Bagdasaryan often use electronic aids -- here they are studying the software.

done on a high level, and already at the beginning of 1972 we were able to submit the machines for state tests. They were passed successfully, and 2 months later intergovernmental tests were conducted by a commission of specialists of the participating CEMA countries. The prototypes proved to be excellent and a rating of 'good' was obtained for series-produced equipment. At the beginning of last year a second stage of state tests was conducted. This time the series-produced model was tested and also received an 'excellent' rating. For the designers and producers this was a real event, perhaps even more significant than obtaining the international medal for the prototype, because not exhibitional models but machines produced in series at the plant are working on production.

"The work on the ES-1030 proved to be very interesting, as it was necessary to solve an entire complex of very intricate problems, but the gravity of the posed tasks was a real stimulus for the mobilization of knowledge, ideas and experience. Before the ES we already had a good school -- the designing and creation of the second-generation machine 'Razdan-3.' Thus formed the circumstances that series production of that computer was not achieved, but the 'Razdan' prototype works efficiently in the institute, doing bookkeeping and other calculations. Such 'repetition' made it easier for us to go over to the new model, with a jump to the next position."

The path of the ES-1030 from institute test-stands to the plant shops also was traveled without compulsory halts and delays. The manufacturer, the Kazanskiy Computer Plant, has treated the matter very seriously and the collaboration of the designers and the plant workers has gradually grown

Chief technologist of the institute E. G. Manucharyan checks each unit with special care.

into real friendship. And it is no accident that among winners of a 1976 State Prize USSR are named Vladimir Salakatov of Moscow, a candidate of technical sciences and supervisor of the design of the internal storage, and Yuriy Sotov of Kazan', section chief of the Special Design Office of the Kazanskiy Computer Plant.

During the time of manufacture, adjustment and tests of the prototype teams of specialists from Kazan' were always present in the institute, the working documentation was presented to the plant workers synchronously with approval and the Yerevan workers in turn handled the creation of test lots at the plant, jointly adjusted the first plant model there and improved the machine until its series production had been organized.

And yet the users had the last word. In testimonials received from very different institutions, research and productive, in one way or another the same thought was expressed: the machine is convenient to control and reliable and failure-free in operation. Such a computer could with complete justification be recommended to foreign partners.

"All work on computers of a given series is done according to a unified program within the framework of the CEMA," emphasizes A. T. Kuchukyan, candidate of technical sciences, section chief and now chief designer of the ES-1030, "specially created councils coordinate the adoption of agreed-upon decisions, which makes it possible in the creation of technical equipment in different countries to have a certain generality in the principles of design and software and guarantees the interchangeability of equipment and units. This makes it possible to organize thorough cooperation between countries, operate machines very economically and organize joint servicing.

The internal storage was designed under the supervision of Candidate of Technical Sciences G. A. Zakharyan.

Candidate of Technical Sciences S. Ye. Kazaryan, deputy chief electronic equipment designer, tests modified machine units.

"Our ES-1030 is relatively simple to manufacture and service, but at the same time has rather good operating characteristics. It is eagerly taken for export and has successfully arrived at the door of contemporary equipment.

"We have formed good creative relations with specialists of the Polish People's Republic, the People's Republic of Bulgaria and the Czechoslovak Socialist Republic. It is very important, when the thinking of various people flows in a single common channel. The mutual contacts permit enriching one another with ideas, distributing the work and as a result creating machines completely meeting contemporary requirements."

Representing winners of the 1976 State Prize of the Armenian SSR in the area of science and technology, Academician V. A. Ambartsumyan gave special attention to a characterization of the machine created and approved by practice.

"A distinctive feature of the ES-1030 is the fact that it is completely constructed of integrated microcircuits and for the first time in Soviet practice in a general-purpose computer storage units of thin cylindrical films were used, which permitted considerably reducing the dimensions and increasing the operating speed and reliability.

"In that model for the first time among ES models a monitoring and diagnostic system has been created which assures restoration of the working capacity of the computer in a minimal time.

"One must also class as merits of the ES-1030 its complete program compatibility with other computers of the Unified System and its modular structure

of construction, which makes it possible to realize various alternatives of the complexing of multimashine systems. One should also note its rich softwear system.

"The ES-1030 is finding application in many branches of the national economy in the USSR and CEMA countries.

"The development and introduction into the national economy of the ES-1030 computer is a considerable contribution to the development of our country's computer technology."

"The high evaluation of the results of the labor of a large collective of specialists working on the creation and introduction into production of that machine cannot help but please us. But for the developers themselves that is an already completed stage and their thoughts are occupied by the future -- the fourth-generation machine. What sort of machine will it be?"

"Without dwelling upon technical details, I will briefly answer -- the new electronic computer will increase the reliability and systems possibilities of the machine higher than its predecessor by an order of magnitude," says the chief engineer of YerNIIMM, Candidate of Technical Sciences M. A. Semerdzhyan. "It will have greater productivity and be three to four times as complex, but the difficulties in that case will in the main walk on the shoulders of the developers, and it will be only one fourth more difficult to manufacture than today's machine. Our machine will meet the better foreign standards and make it possible to expand the sphere of application of electronic computers."

...Time sets its rigid limits. The cycle of creation of a computer from the idea to the introduction into production is about 7 years under present conditions, and the lifetime of each generation of machines until obsolescence is 4 to 5 years. What was even yesterday a technological achievement becomes an anachronism today. The dialectics of the creativity of the contemporary developer of computers requires ruthless revision of ideas for ascent to a higher stage. It seems not long ago at all that the creators of the popular "Nairi-3" machine received congratulations and were awarded a State Prize USSR, and today the development of the 1970 level seems a stage passed through long ago. And the "Nairi-4" has been presented to a court of experts; of it A. A. Dorodintsyn has said that in its main physical characteristics and structural solutions it has no analog and surpasses existing models of that family and other Soviet computers of such a class. Today this sounds grandiose, but the developers already really face problems and difficulties in the creation of fifth-generation machines. The creators of the ES-1030 also will seek in the future new puzzles and new ways to solve them. I would like to wish all investigators successes and creative anxiety, without which there is not and there cannot be victory.

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'ELEKTRONIKA K-2000' MICROELECTRONIC CONTROL COMPUTER COMPLEX AND ITS APPLICATION

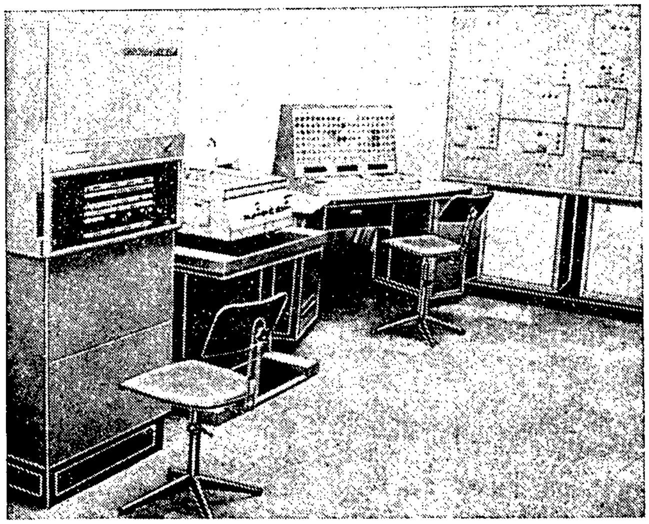
Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 6, Nov/Dec 76 pp 128-130 manuscript received 2 Aug 76

[Article by Vitaliy Mikhaylovich Val'kov, candidate of technical sciences, Leningrad: "The 'Elektronika K-2000' Microelectronic Computer Complex and Its Ranges of Application"]

[Text] Of principal importance in designing integrated hierarchical production control systems is the equipment used for the central control link, which can make possible on one hand maximum efficiency with regard to functioning of lower-level local links based on mini- and microcomputers (by coordinating their operation), as described in [1], and on the other the feasibility of linking up with the upper level of production control and of control over the enterprise as a whole. The TsVM [central processor] of a control computer complex which solves the problem of a central link (of a hybrid, process systematization nature) should have first of all a developed priority interrupt system, the ability of addressing a great number of information sources and collectors, and also a memory of relatively high capacity (including NMD [disk storage] and/or NML [tape storage]), as in [2]. The UVK [control computer complex] should contain as part of its structure, in addition to equipment for linking with the controlled system, efficient devices for linking with operating personnel, communication channels (including selective and program controlled), and devices for exchanging with the UVK (VK [computing complex] or IVK [data processing complex]) of other hierarchical levels [3]. The presence of these characteristics of course does not exclude the use of these UVK's for independent control of a group of processing systems on a time-sharing basis or for centralized monitoring and control of complicated processing systems.

The "Elektronika K-2000" UVK, totally compatible with regard to architecture and software with mass-produced "Elektronika K-200" UVK's, was developed for the technical applications indicated above primarily in the electronics and related industries. The technical-economic feasibility of developing it was determined by the presence of a large systems surplus with regard to application of the "Elektronika K-200" UVK in the Ninth Five-Year Plan [4]. Use

of this surplus in circulating and designing new total ASUTP's [automated systems for controlling manufacturing processes] based on a microelectronic high-speed (more than 100,000 operations per second), more practicable analog promises to reduce the time required to develop and put systems into operation while achieving higher parameters.



The "Elektronika K-2000" UVK, as far as its basic equipment is concerned, is designed as a single equipment rack (cf. photograph) having four standard "shelves," each of which contains an OZU [direct-access memory unit] with a capacity of 1K 24-bit words and a PZU [read-only memory unit] with a capacity of 4K 24-bit words. Thus the basic UVK has an OZU with a capacity of 4K words and a PZU with a capacity of 16K words, which, in conjunction with disk stores, makes it possible to satisfy the requirements of a memory unit for a wide range of total ASUTP's [5]. The total memory field capacity of the TsVM is 48K words, which makes it possible, when necessary, to increase the number of OZU's and PZU's by using additional racks.

Each shelf of the rack, including the TsVM's shelf (with a control and monitoring panel) contains, in addition to memory units and power supplies, 25 standard plug-in modules. The use of a four-in-one printing module has made it possible to obtain relatively high packaging density at the equipment level--the functional complexity of a module is the equivalent of that of six TEZ's [tabulating and writing elements] in a YeS-series computer. In addition to the set of processor modules, the basic structure of the UVK includes the following pieces of equipment, which are designed as standard modules and take up an additional one and one half shelves of the rack:

Decoder (64 + 2 X 8 addresses)	1
Unit for DC-coupled digital input without recall (4 channels X 23 bits)	2
Matching unit (42 amplifiers)	2
Analog-voltage-to-digital converter (12 bits)	1
Analog signal commutator (0 $\pm$ 10 V)	128 inputs
Digital-to-analog-voltage converter (0 $\pm$ 10 V)	4 channels
Unit for AC-coupled digital input with recall (2 channels X 12 bits)	1
Unit for parallel digital output with recall, amplification, and bit-by-bit clearing (4 channels X 23 bits)	2
Interrupt preregister (2 channels X 12 bits)	4
Precise timer with a frequency divisor of 25, 60, 10, 10, and 4	1
Quartz oscillator (10 kHz)	1
Selector channel	1
Control unit for disk storage (two YeS-5052's)	1
Teletype control unit	1
Unit for exchanging with "Videoton-340" displays (as many as 8)	1

The main logic elements of the processor and the equipment listed (except the disk storage control unit, which is made up of series-133 IC's) are large series-K-834 hybrid integrated circuits. The main component of analog-digital and digital-analog conversion equipment is the series-250 12-bit hybrid converter. It is also possible to include in addition in the UVK input-output equipment which comes with the "Elektronika K-200" UVK, as well as equipment for communicating with operating personnel. The maximum number of addressable input-output units (channels) which can be included in the new unit is 15,630.

One of the main factors which speaks for the bright prospects of the "Elektronika K-2000's" application is the total compatibility of this new package with the "Elektronika K-200" UVK as far as software is concerned, which in its totality consists of 100,000 program steps and includes, in particular:

A standard operational system and a number of problem-oriented versions of this system which make possible the UVK's high efficiency when operating in the multiprogram mode in real time.

Problem-oriented standard subsystems developed as the basis for software systems for total ASUTP's [6].

Standard software for dialog between operating personnel and the TsVM in meta natural languages of users [6].

Developed interpreting systems for automation of programming and adjusting programs for TsVM's of the M-220 and "Minsk-32" type.

The main areas of application of this new UVK are shown in the following table:

Major Areas of Application of the "Elektronika K-2000" UVK

Control Systems	Main Jobs Performed
Total ASUTP's at enterprises for manufacturing electronic products and other enterprises engaged in discontinuous and discontinuous-continuous production (manufacture of oxide semiconductor and ceramic capacitors, kinescopes, IC's, televisions, etc.)	Coordinating operation of local ASUTP's. Automated recordkeeping of production progress, including monitoring fulfillment of the assortment quota, operation-by-operation statistical monitoring, visualization and documentation of condition of flowlines and equipment. Automatic link with the ASUP, including transmission of "quota-actual" information.
Systems for group control of production units (sections for manufacturing aluminum foil, units for etching and forming and for cutting out precision resistors, photocomposition units, etc.)	Controlling operation of machinery on a time-sharing basis. Solving problems of optimum control of the main operation in each unit. Scheduling and keeping records of the work done by each section.
Systems for automated (automatic) control of benches for inspecting and testing complicated products (manufacture of turbogenerators, bodies of aircraft, etc.)	Centralized monitoring and mapping on a real time scale of the values of parameters of products and outside influences. Control of the progress of product tests, including simulation of outside influences. Statistical analysis and documentation of results of monitoring and testing.
Systems for automated monitoring and control of complicated industrial systems (nuclear power plants, major assembly lines at machine-building enterprises, etc.)	Centralized monitoring and detection of deviations. Taking control steps to stabilize and optimize the process cycle. Reflecting the condition of the system by means of graphic control charts and panels for operating personnel. Documentation of the progress of the industrial process.

Relatively extensive application of the "Elektronika K-2000" UVK and its modifications is being made possible by the development of packages of equipment for communicating with operating personnel and of equipment for automatic exchange with YeS computers and the first models of microcomputers, as well as by expansion of the set of standard programs oriented toward monitoring and controlling production processes. Mass production of the "Elektronika K-2000" UVK is planned to begin in the first half of 1977.

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MAN'S INFLUENCE ON THE EARTH'S ATMOSPHERE

Moscow PRIRODA in Russian No 4, Apr 77 pp 10-19

[Article by B. M. Smirnov]

Boris Mikhaylovich Smirnov, Doctor of Physical and Mathematical Sciences, heads a laboratory at the Atomic Energy Institute imeni I. V. Kurchatov. He is a specialist in the field of elementary processes in plasma, gas and the atmosphere. He is author of the monographs: ATOMNYYE STOLKNOVENIYA I ELEMENTARNYYE PROTSESSY V PLAZME, Moscow, 1968; FIZIKA SLABOIONIZOVANNOGO GAZA, Moscow, 1972; VVEDENIYE V FIZIKU PLAZMY, Moscow, 1975, and others. He has published an article in PRIRODA (in collaboration with A. A. Ivanov and V. A. Legasov) entitled "Plasma Chemistry" (No 4, 1975).

[Text] The problem of a change in the physicochemical properties of the atmosphere is attracting the attention of an ever-increasing number of specialists. Now there is no longer any doubt that to a considerable degree these changes are a direct or indirect result of man's productive activity. The influence of man on the developing composition of the atmosphere is reflected, in particular, in an increase in the carbon dioxide content and in the contamination of air by impurities destroying the earth's ozone layer. That is why it is extremely important to visualize what might be the result of further development of these processes.

It is precisely these matters which are addressed in the article by B. M. Smirnov, entitled "Man's Influence on the Earth's Atmosphere" and the article by I. I. Vol'nov entitled "Anthropogenic Contamination of the Atmosphere by Freons and its Possible Consequences."

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A characteristic of recent centuries has been a continuous growth in the scales of man's influence on the environment, reaching out beyond individual localities and assuming a global nature. In such a situation there must

be a scientific recognition of the consequences of man's interaction with the environment with respect to individual parameters. This will make it possible to determine the changes in nature with the further development of human society and the measures which should be taken in good time in order to save the environment from the undesirable influence of man.

We will discuss only one of the elements of the environment: the earth's atmosphere. Under the conditions of human life it plays, first of all, a definite role in the earth's heat balance and we experience the totality of energy processes in the earth's atmosphere as the weather. Second, the physicochemical properties of the atmosphere exert an influence on ensuring man's life.

The local effect of production on the atmosphere long ago became appreciable. The clearest confirmation of this is the atmosphere of a large city. The heat balance and the water vapor balance here differ appreciably from the corresponding characteristics for the surrounding area. The temperature of a large city on the average is 1.2-2° higher (on clear winter nights this difference attains up to 10°), humidity is greater and the velocity and frequency of occurrence of the winds is lower than in the surrounding area.

With respect to physicochemical properties, an urban atmosphere also has its differences. It contains considerably greater quantities of dust (an order of magnitude greater than over a rural area and two orders of magnitude greater than over the ocean) and a greater quantity of aerosols. Therefore, the intensity of solar radiation at the earth's surface in a city is 10-20% lower and the intensity of the UV radiation is several times less than for the surrounding area. In addition, there is a whole series of impurities forming in the atmosphere associated with the operation of industrial enterprises and transportation[1].

A characteristic manifestation of the interaction between solar radiation and the urban atmosphere is a photochemical smog. Its appearance is caused by the transpiring of chemical processes occurring with the participation of UV radiation, ozone, nitrogen oxides, and also organic compounds, effluent from industrial enterprises and transportation. Under conditions favorable for smog these processes lead to the formation of carcinogenic organic substances which have a lethal effect on living organisms even at a low concentration[2].

Thus, the local influence of man on the atmosphere is considerable. Since the scale of production is increasing, at a definite stage in development the global influence of man on the atmosphere will become significant and this will be manifested over the entire earth as a whole. Our task is a clarification of the possible methods for man's influence on the earth's atmosphere and the effects to which this can lead.

Now we will estimate at what scales of production the influence of man on the earth's heat balance will become appreciable. In accordance with the usual assumptions we will assume that such an influence is appreciable if the effect of the energy sources created by man causes an increase in the temperature of the earth's surface by 1°. In this case there is an appreciable change in the rate of the processes of development of plants, animals and microorganisms.

In evaluating the limiting intensity of energy release we take into account that the earth radiates almost as an ideally black body. The mean intensity of IR radiation at the earth's surface is $1.97 \cdot 10^{14}$ KW, which corresponds to a temperature of the earth's surface T = 288°K. According to the Stefan-Boltzmann law, a change in the intensity of radiation from the earth's surface by the value $\Delta\Upsilon$ and a change in surface temperature ΔT are related as follows:

$$\Delta\Upsilon = \Upsilon \frac{4\Delta T}{T}.$$

It follows from the cited expression that the influence of man on the earth's heat balance will become significant when the quantity of consumed energy attains the level $3 \cdot 10^{12}$ KW. At the present time this index (it is dependent primarily on the quantity of combusted fuel -- coal, petroleum, gas) is 10^{10} KW. If the growth of energy consumption (4% per annum) is maintained as in the preceding years, the resulting figure will be attained in approximately 150 years. We note that the result will make it possible to answer only the question as to at what scales of production its influence on the earth's heat balance will become significant. At the same time we cannot say whether this influence will be favorable or unfavorable. This will require more detailed investigation. In addition, it must be taken into account that the specific nature of production can lead to a change in the heat balance on the earth even in the case of a more modest level of energy consumption. In order to take this circumstance into account it is necessary to ascertain the most important relationships between the productive activity of man and natural processes. After comparing the quantitative characteristics (mean energy fluxes at the earth's surface) of productive and natural processes it is possible to understand the importance of the specific type of human activity and its influence on nature. The comparison shows that the artificial processes as a rule are considerably weaker than natural processes, although locally they can be rather intensive. Accordingly, at the present time an appreciable influence of man on processes in the atmosphere can be manifested only in limited regions in space.

However, there is an indirect method for man's modification of the earth's atmosphere. The earth's heat balance is dependent on the optical properties of the atmosphere. They determine absorption and scattering of solar shortwave radiation and also absorption and radiation of IR radiation. The principal components of the atmosphere -- molecular nitrogen and oxygen, as

well as argon -- are optically transparent. The absorptivity and emissivity of the earth's atmosphere are governed by the gases present in the atmosphere in small quantities (water vapor, carbon dioxide, ozone, etc.). For example, atmospheric ozone absorbs 2-3% of the solar radiation passing through the atmosphere, although its mass is approximately $2 \cdot 10^6$ times less than the mass of the atmosphere.

Since the productive activity of man is accompanied by contamination of the atmosphere by different chemical agents, some of them, exerting an influence on the optical properties of the atmosphere, can cause a change in the earth's heat balance. We will now clarify what limits such an effect of man on the earth's atmosphere. We will assume that we have added a whole series of different molecular components to the atmosphere, making it optically translucent. In this case all the IR radiation of the earth's surface is absorbed by the atmosphere. We will determine to what change in the mean temperature of the earth's surface this will lead.

It follows from the condition of thermal equilibrium of the earth and atmosphere that the total intensity of radiation into surrounding space should be equal to the intensity of the solar radiation incident on the atmosphere. Then the "contaminated" atmosphere should additionally emit $1.0 \cdot 10^{13}$ KW of IR radiation, which earlier was emitted by the earth's surface and not absorbed by the atmosphere. We will assume that in the case of a "contaminated" atmosphere there is retention of the earlier existing proportions between the fluxes of atmospheric IR radiation in the direction of the earth and space, between the fluxes of energy from the earth's surface emitted by it as a result of thermal radiation, evaporation and convection. In addition, we will assume that under the new conditions the nature of the interaction between short-wave radiation and the surface of the earth and atmosphere will not change. Then the new parameters of the heat balance will lead to an increase in temperature of the earth's surface by less than 5°.

We note that any contamination of the atmosphere by the molecular components causes simultaneously the formation of aerosol in it which partially reflects the solar radiation and thereby favors a decrease in the earth's temperature. Therefore the limiting figure which we obtained, corresponding to an increase in the mean temperature of the earth's surface in the case of contamination of the atmosphere by molecular components is clearly exaggerated. But even in this case the changes in different energy fluxes in the earth's heat balance under the conditions of the "mental" experiment which we carried out are small in comparison with their values in the free atmosphere.

At the present time the contribution of man's productive activity to atmospheric contamination is small in comparison with its natural contamination. (An exception is the production of freons, which do not form naturally). Accordingly, the influence of man's productive activity on the earth's heat balance as a result of change in the optical properties of the atmosphere

for the time being is small, although a local effect of such a type can be extremely significant.

The analysis indicates that at the present stage in the development of production its influence on the earth's heat balance is small. The same conclusion can be drawn from an analysis of other properties of the atmosphere associated with its content of dust and aerosol. And the following question arises: how this specific effect of man on the earth's atmosphere will change with a further development of production and to what results this will lead.

Next we will examine these problems applicable to the accumulation of carbon dioxide since the most intensive aspect of man's activity is associated with the combustion of fuels, accompanied by a considerable escape of carbon dioxide into the atmosphere. On this matter there is reliable information which will make it possible to draw definite conclusions concerning the future.

In the atmosphere the mean concentration of carbon dioxide at the present time is $3.25 \cdot 10^{-4}$. The total quantity of carbon in atmospheric carbon dioxide is not much less than 700 billion tons. Annually during photosynthesis on land and in the ocean, and in the dissolving of carbon dioxide in the ocean from the atmosphere there is absorption of about 150 billion tons of carbon and approximately the same quantity is released in the putrefaction and breathing processes. Man exerts an appreciable influence on the balance of carbon dioxide present in the earth's atmosphere. The annual production of coal, petroleum and gas at the level of 1976 exceeds 6 billion tons. These fossil fuels after combustion pass into the atmosphere in the form of carbon dioxide, which contains not much less than 5 billion tons of carbon. This is already an appreciable influence. We will trace to what changes it will lead.

Precise measurement of the concentration of carbon dioxide in the atmosphere is a serious problem. As a result of the simultaneous release and absorption of carbon dioxide on the earth its concentration at a selected point on the earth can change considerably in dependence on time of day, season and nature of the environment.

For determining stable trends in the change in the global concentration of carbon dioxide it is necessary to make a great number of measurements in places remote from the sources and absorbers of carbon dioxide (cities, oceans and localities covered by vegetation), for example, the carrying out of measurements at great altitudes. With respect to surface observations, for such a purpose a unique place is the Mauna Loa Observatory (Hawaiian Islands), where beginning in 1958 careful measurements have been made of the carbon dioxide concentration. Due to the nature of the winds and the elevation (about 3,800 m above sea level) at which the observatory is situated and also the great distance to the nearest sources of atmospheric contamination, which are located at a distance of several thousand kilometers

from the observatory, this site became the center of the most reliable information on this parameter.

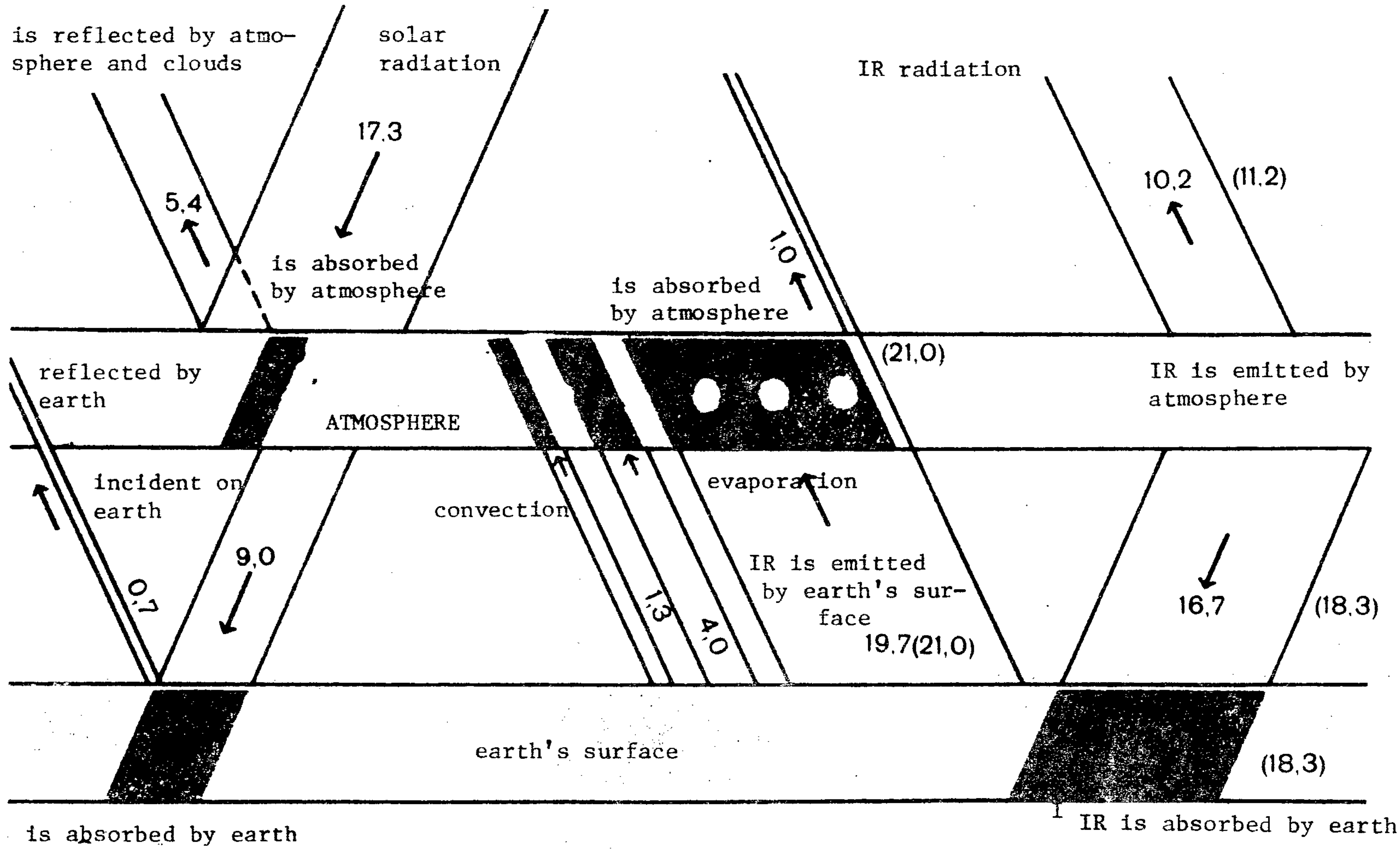
By extrapolating the data obtained during measurements of the concentration of carbon dioxide in the atmosphere during the period 1958-1972, we find that from 1958 through 1976 its concentration increased by 4%[4]. Thus, there is a tendency to an increase in the quantity of carbon dioxide in the atmosphere, associated with man's productive activity. If all the carbon dioxide forming during the combustion of fuels remained in the atmosphere, its increase during the considered time interval would be about 10%. Accordingly, most of the industrial carbon dioxide is absorbed from the atmosphere by other cycles.

For example, such absorption can be associated with the dissolving of carbon dioxide in the ocean. However, in the upper layers of the ocean, effectively exchanging carbon dioxide with the atmosphere, its content does not exceed the atmospheric level. Accordingly, if it is assumed that during the considered years the parameters of the upper layers of the ocean do not change, the escape of industrial gas from the atmosphere into the ocean is excluded. It remains to assume that this escape effect must be associated with an intensification of photosynthesis as a result of human activity.

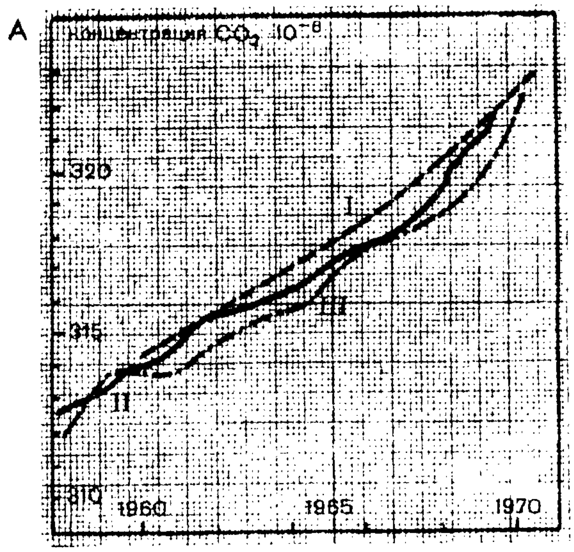
It is well known that in photosynthesis the energy of solar radiation is partially transformed into chemical energy by means of "reworking" of atmospheric carbon dioxide into the organic matter of plants. The optimum conditions for photosynthesis are attained when the concentration of carbon dioxide in the atmosphere is several percent. Since this index is far from optimum and is only hundredths of a percent, the plants experience a "shortage" of carbon dioxide and any change in the content of carbon dioxide, other conditions being favorable, should cause a proportional change in the effectiveness of photosynthesis. During the last 18 years the carbon dioxide content in the atmosphere has increased by 4% and therefore, other conditions being favorable, the rate of photosynthesis increased by 4%[5].

It is difficult to estimate the influence of man's agricultural activity on the photosynthesis process. The scales of this activity are great. The annual world yield (total quantity of organic matter collected from cultivated lands) contains 2-3 billion [tons?] of carbon. The energy stored in it is only half as great as the energy annually consumed in the combustion of fuels. In order to obtain this yield man uses 10% of the land. Therefore, in the future we will take into account the influence of man's agricultural activity on the cycling of carbon in all nature.

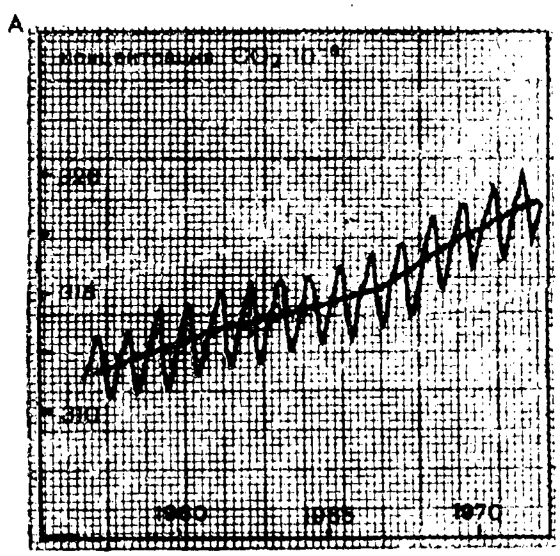
The fraction of organic matter decomposing in processes of vital functioning of plants and animals is proportional to its quantity provided the other conditions of the course of these processes do not change. The same applies to the rate of the process of release of carbon dioxide from the ocean. Taking this into account, we can visualize a picture of the balance of carbon in nature, taking man's activity into account in the following way. There



Heat balance of earth and atmosphere. Quantity of energy "reworked" by earth's surface and atmosphere expressed in 10^{13} KW. Enclosed in parentheses are the new parameters of the earth's heat balance corresponding to the hypothetical change in the optical properties of the atmosphere. The shading represents absorbed radiation.



Mean annual concentration of carbon dioxide [from M. Ye. Berlyand, 1975]. I) aircraft measurements over Scandinavia; II) aircraft measurements near the south pole; III) data from Mauna Loa Observatory. A) CO_2 concentration



Mean monthly and mean annual [smooth curve] concentrations of carbon dioxide near Mauna Loa Observatory. Oscillation structure of the mean monthly curve is attributable to the fact that the main absorption of carbon dioxide as a result of photosynthesis is related to the middle of the year because it occurs in the northern hemisphere (from NATURE, Vol 255, p 137, 1975). A) Concentration

Energy Fluxes at Earth's Surface and in Atmosphere -- Natural and Artificial

Source	Energy flux, KW/km^2
Mean flux of solar radiation	$4 \cdot 10^5$
Evaporation, convection	$4 \cdot 10^5$
Energy generation in cyclone	$2 \cdot 10^4$
Energy consumption in well-developed industrial region (Ruhr, West Germany)	$2 \cdot 10^4$
Photodecay of ozone	10^4
Level of artificial energy release at which temperature at earth's surface increases by 1°	$5 \cdot 10^3$
Energy of wind "reworked" in atmosphere	$2 \cdot 10^3$
Energy consumption in country with well-developed industry (Japan)	$2 \cdot 10^3$
Energy release level at which photochemical smog can begin	10^3
Photodecay of molecular oxygen in atmosphere and ozone formation	200
Photosynthesis	200
Heat flux from earth's deep layers	60
Mean consumption of energy of artificial origin	20
Earthquakes	0.3
Volcanic eruption (average)	0.3
Formation of bound nitrogen* in nature	0.08
Production of bound nitrogen as a result of human activity	0.08
Maintenance of natural quantity of NO in stratosphere**	0.002
Electrical current in atmosphere	0.001

* Energy is computed in the process: $2N_2 + 6H_2O \rightarrow 4NH_3 + 3O_2$.

** Energy expenditures are the same as in a high-temperature apparatus.

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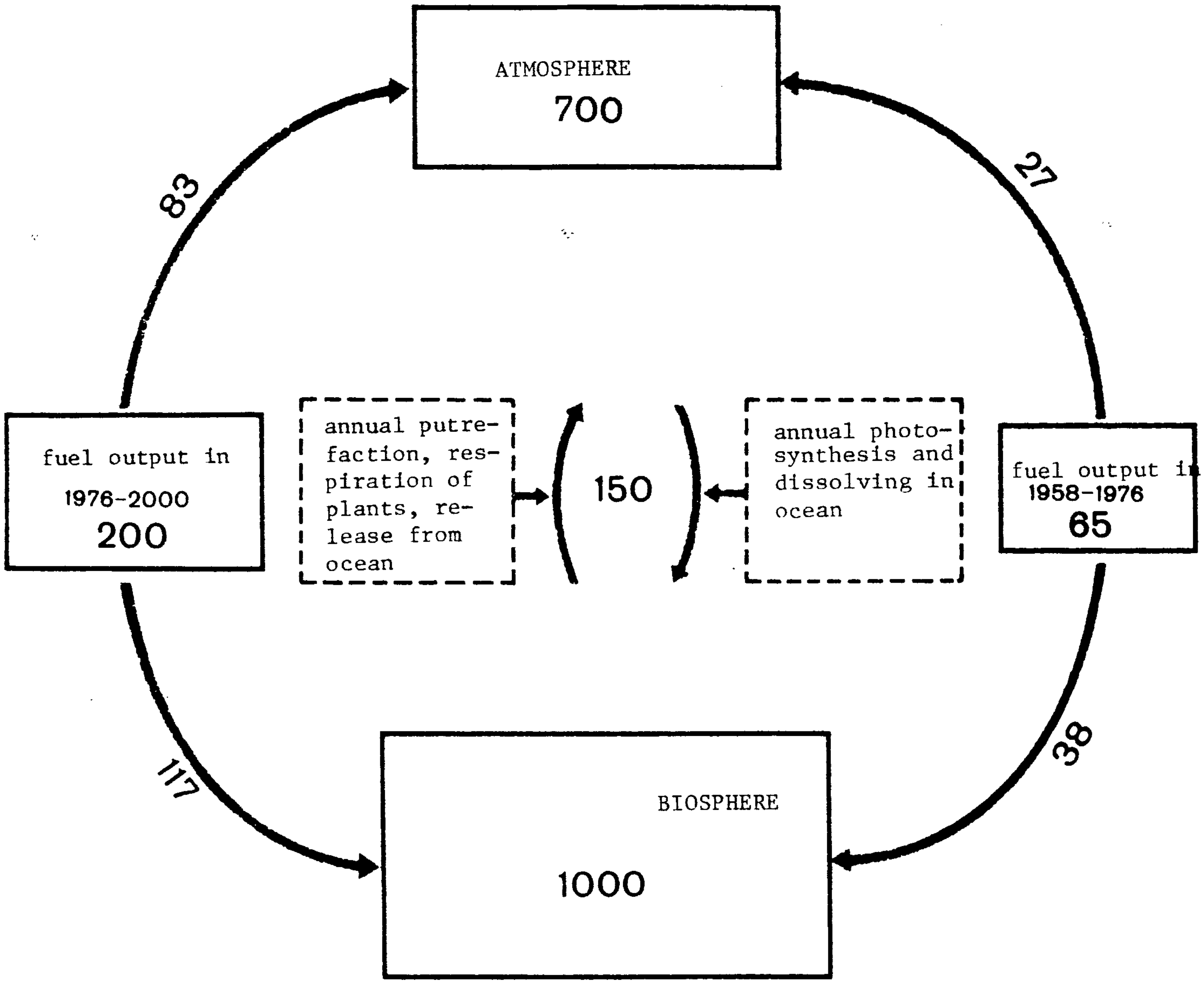
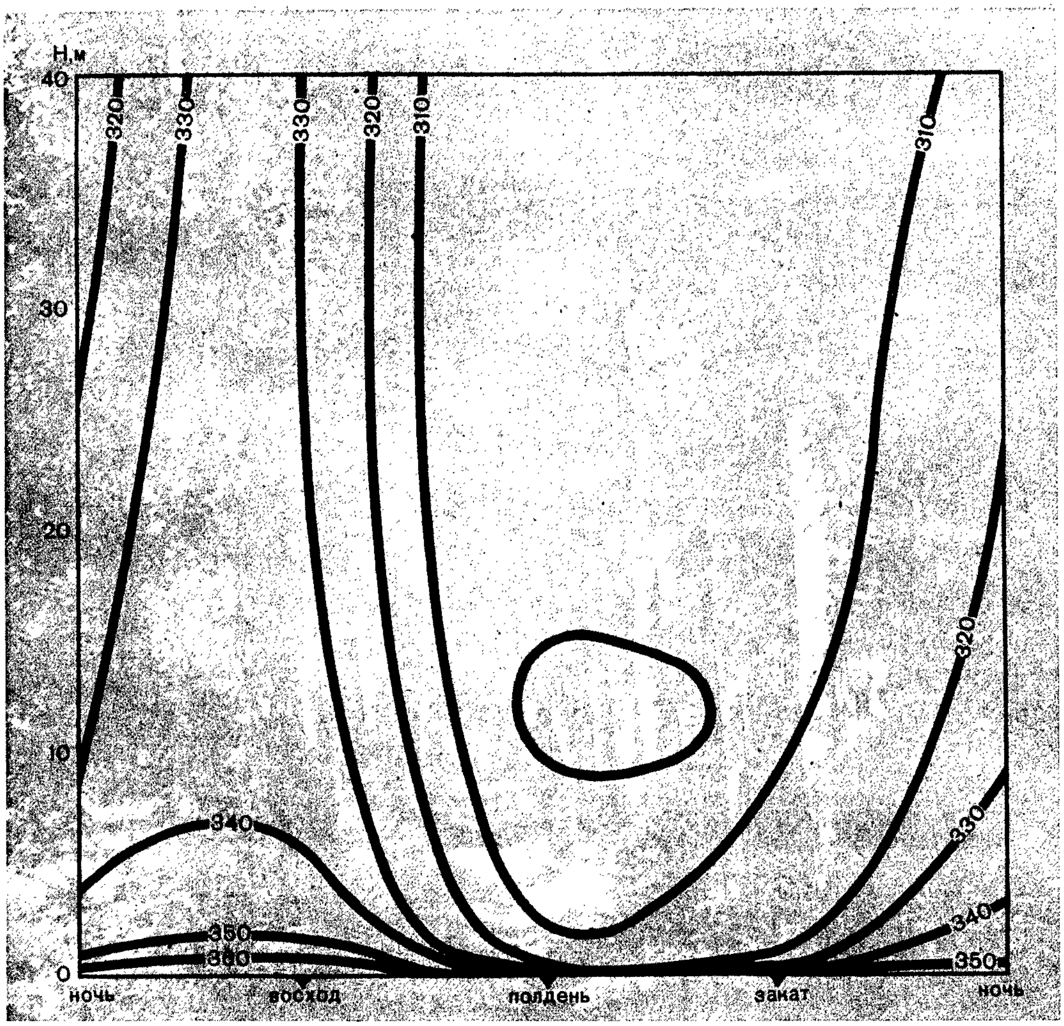
is a rapid exchange of carbon (in the course of several years) between the atmosphere and the biosphere. With an increase in the quantity of carbon dioxide in the mentioned cycles due to the combustion of fuel the relative content of carbon in each of them does not change because simultaneously between them there is an increase in the fluxes of carbon, proportional to its total quantity. In this scheme reference is to the mean temporal characteristics and no allowance is made for slow processes associated with the transfer of carbon into the deep layers of the earth or with its natural escape from there.

Thus, man is incorporated in the carbon exchange processes transpiring on earth between the near-surface layers of the earth and the atmosphere and increases the quantity of carbon present in the cycle. It should be



Carbon cycles and carbon balance (billions of tons).



Night Sunrise Midday Sunset Night

Distribution of concentration of carbon dioxide (in 10^{-6}) with height in forest in course of day. It is shown that there is a strong dependence of this value on time of day and the height at which the measurements were made. (From SCIENTIFIC AMERICAN, Vol 3, No 3, 1970)

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understood to what changes this later leads and how these changes are reflected in the conditions for human life.

Assuming that the output and use of fuels will occur at the same rates as in the preceding 25 years and that this will be 4% per year[6], we find that in the year 2000 as a result of the combustion of fuels approximately 13 billion tons of carbon will enter the atmosphere. During these 25 years 200 billion tons of carbon will be emitted into the atmosphere. Taking into account the exchange of carbon dioxide with the earth's surface, this

will lead to an increase in the concentration of CO_2 in the atmosphere in only 25 years by 12%. Under the considered conditions the concentration of carbon dioxide in the atmosphere in the year 2000 will be $3.64 \cdot 10^{-4}$. The resulting change in atmospheric composition should not be reflected in human health. Approximately such a change in the carbon dioxide concentration occurs in the course of five minutes due to the breathing of one man in a room with a volume of 35 m^3 with the windows closed. Such an accumulation of carbon dioxide can give positive results associated with an intensification of photosynthesis. All other conditions being favorable, this can lead to an increase in yields in the year 2000 by a factor of 1.1 due to an increase in the quantity of carbon dioxide.

Molecular Components in Atmosphere (According to E. Almqvist)

	Компонент 1	2 Концентрация, 10^{-6}		3 Эмиссия, млн т в год		Время нахождения в атмосфере у поверхности Земли 8
		4 Большой город	5 сельская местность	5 естественная 6	в результате деятельности человека 7	
9	Углекислый газ	328	325	$5 \cdot 10^5$	$2 \cdot 10^4$	5 лет 22
10	Окись углерода	5	0,1	10^3	300	0,1—3 года 23
11	Водяной пар	$(0,3-6) \cdot 10^3$	$(0,3-6) \cdot 10^3$	$4 \cdot 10^8$	—	10 дней 24
12	Двуокись серы	0,2	0,032	$4 \cdot 10^3$	100	5 дней
13	Сероводород	0,024	0,032	100	3	2 дня 24
14	Озон	0,3	0,02	10^5	—	10 дней
15	Окись азота	0,2	0,001	500	100	5 дней
16	Двуокись азота	0,1	0,001			
17	Закись азота	0,5	0,3	600	—	4 года 23
18	Аммиак	0,01	0,006—0,02	$6 \cdot 10^3$	4	2—5 дней
19	Углеводороды	2,0	0,001	200	40	—
20	Метан	3	1,5	1400	100	3 года
21	Фреоны	$(1-2) \cdot 10^{-4}$	$(0,5-1) \cdot 10^{-4}$	—	0,8	50—70 лет

1) Component; 2) Concentration; 3) Emission, millions of tons per year; 4) large city; 5) rural area; 6) natural; 7) as a result of human activity; 8) Time of presence in atmosphere near earth's surface; 9) Carbon dioxide; 10) Carbon monoxide; 11) Water vapor; 12) Sulfur dioxide; 13) Hydrogen sulfide; 14) Ozone; 15) Nitric oxide; 16) Nitrogen dioxide; 17) Nitrous oxide; 18) Ammonia; 19) Hydrocarbons; 20) Methane; 21) Freons; 22) years; 23) year; 24) days

Now we will estimate the influence of accumulation of carbon dioxide in the atmosphere on the earth's heat balance. Computations show that the doubling of the quantity of carbon dioxide in the atmosphere will lead to an increase in the temperature at the earth's surface by 1.5-2°. These computations and the mechanical use of their results in a real situation lead to incorrect conclusions concerning the influence of the accumulation of carbon dioxide in the atmosphere on the heat balance of the planet. Since such an error is widespread in the popular literature, we will discuss this matter in greater detail.

The results of typical computations relating to the influence of carbon dioxide in the atmosphere on the earth's temperature can be summarized as follows. The thermal radiation of molecules of carbon dioxide is associated with some vibrational-rotational transitions occupying a definite part of the IR spectrum. If the atmosphere is absolutely transparent in this region of the spectrum, the addition of carbon dioxide to it will lead to an additional flux of IR radiation from the atmosphere to the earth's surface, due to which the surface temperature is increased. This part of the spectrum becomes saturated so that a further increase in the content of carbon dioxide is not reflected in atmospheric emissivity in this part of the spectrum but leads to the appearance of radiation in a new region due to the transition of molecules present in highly excited vibrational and rotational states. But since the fraction of such molecules is small, the considered effect will be insignificant and the addition of the existing quantity of carbon dioxide will lead to a considerably lesser change in the heat regime of the atmosphere in comparison with the case of its elimination from the atmosphere.

A still weaker effect of addition of carbon dioxide is observed in a case when the atmosphere contains other components whose absorption (and emission) spectra overlap with the absorption spectra of carbon dioxide. And there are such components in the atmosphere. The earth's surface emits an average of $1.97 \cdot 10^{14}$ KW of energy in the form of IR radiation and only a small part of this radiation with a power of $1.1 \cdot 10^{13}$ KW is not absorbed by the atmosphere. Accordingly, the atmosphere absorbs (and this means, emits) in almost the entire spectrum of the earth's thermal radiation.

Change in Temperature of the Earth's Surface After Addition of Carbon Dioxide to Transparent Atmosphere Not Containing Carbon Dioxide

Изменение температуры поверхности Земли 1		Колебательный переход, см$^{-1}$ 2					
		3 основные переходы			4 лазерные переходы		все переходы 5
		617	667	717	961	1064	
	добавление количества углекислого газа, содержащегося в атмосфере в настоящее время 6		11,65		0,45	0,25	12,35
	добавление количества углекислого газа, вдвое превышающего современное значение 7		12,80		0,68	0,38	13,96
	разность 8		1,25		0,23	0,13	1,61

1) Change in temperature of earth's surface; 2) Vibrational transition; 3) main transitions; 4) laser transitions; 5) all transitions; 6) addition of quantity of carbon dioxide present in atmosphere at present time; 7) addition of quantity of carbon dioxide double the present content; 8) difference

However, if it is assumed that the spectral region in which carbon dioxide emits is not overlapped by the emission spectrum of other atmospheric components, then an increase in its content by 10% will lead to an increase in the earth's temperature by 0.2°. The use of the spectral characteristics of the real atmosphere with a mean water vapor content (pressure 8 mbar) gives a temperature increase by 0.04°; only about half this change is associated with the main transitions. It can therefore be concluded that the thermal effect from the observed accumulation of carbon dioxide in the atmosphere is insignificant and can be neglected. However, the opinion often expressed in the popular literature concerning the importance of accumulation of carbon dioxide for the thermal regime of our planet is incorrect because it does not take into account the real properties of the atmosphere.

In summarizing, we note that the increase in the quantity of carbon dioxide in the atmosphere has been caused by the productive activity of man -- by the combustion of fuels, and if the rates of increase in fuel production persist in the future, when we arrive at the 21st century the content of carbon dioxide in the atmosphere will increase by 12% in comparison with the present-day level. For practical purposes this will be reflected only in the effectiveness of photosynthesis and will lead to some increase in crop yields on the earth. Accordingly, the accumulation of carbon dioxide in the atmosphere will be favorable for man.

This conclusion requires a reexamination of the general attitude toward the problem of the interaction between man and his environment. It is usually assumed that any unplanned interaction between man and his environment, causing large-scale changes in it, is dangerous and it must be avoided. In actuality, any impairment in the balanced relationships in nature, established over the millions of years, causes dangers because it can lead to consequences which cannot be corrected. However, the considered example shows that such conclusions are not always correct and before they are drawn one must reliably analyze the consequences of the changes brought about.

FOOTNOTES

1. Ebbe Almqvist, AMBIO, Vol III, No 5, p 161, 1974.

2. AEROSOLS AND ATMOSPHERIC CHEMISTRY, New York-London, 1972.

3. The carbon dioxide concentration is the ratio of the number of carbon dioxide molecules to the total number of air molecules.

4. NATURE, Vol 255, p 137, 1975.

5. A. A. Nichiporovich, "Photosynthesis and the 'Sum of Life' on the Earth," BUDUSHCHEYE NAUKI (Future of Science), Moscow, p 164, 1974.

6. This figure should be regarded as an upper limit because by the year 2000 the production of atomic energy will be important and the practical use of thermonuclear synthesis will evidently have been introduced. In addition, the problem of the limitations on the reserves of fuels will be felt more acutely. All this will lead to a decrease in the rates of growth of fuel production.

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ANTHROPOGENIC CONTAMINATION OF THE ATMOSPHERE BY FREONS AND ITS POSSIBLE CONSEQUENCES

Moscow PRIRODA in Russian No 4, Apr 77 pp 19-24

[Article by I. I. Vol'nov]

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[Text] Ozone constitutes one millionth part of the atmosphere and is concentrated for the most part in the stratosphere, that is, in the limits 15.2-60 km from the earth's surface. Ozone has exceedingly great absorption in the UV spectral region. At a wavelength of 0.25 μm it absorbs more strongly than any metal in the visible part of the spectrum. Therefore, the layer of atmospheric ozone completely protects the organic world from the lethal effect of the ultraviolet part of solar radiation with a wavelength less than 0.2 μm. On the other hand, ozone absorption in the IR part of the spectrum in the band 9.5 μm, lying near the maximum of the earth's radiation, has the result that about 20% of the earth's radiation is not transmitted by ozone and this hinders cooling of the earth. Hence the role of ozone in the energy balance of the earth's atmosphere becomes clear. The content and movement of ozone in the atmosphere also exerts an influence on meteorological conditions. That is why the problem of study of the influence of man on the earth's ozone layer is becoming an important part of the global problem of preserving the environment.

The presence of ozone in the atmosphere is attributable for the most part to the fact that in its upper layers (approximately at an altitude of 50 km) the oxygen molecules are split by radiation shorter than 2000 A into

atoms in accordance with the reaction equation:

$$O_2 + h\nu \rightarrow 2O.$$

The oxygen atoms and molecules with the participation of some third particle M form ozone as a result of triple collision:

$$O + O_2 + M \rightarrow O_3 + M.$$

(The M particle absorbs the excess of energy released during the joining of the first two particles.) However, together with the process of ozone formation, there is a process of its destruction. For the most part such a breakdown is attributable to the action of radiation in the UV region with an absorption maximum at 2550 A. This radiation decomposes the ozone molecules and oxygen molecules and atoms are again formed:

$$O_3 + h\nu \rightarrow O_2 + O.$$

The oxygen atoms, in turn, also decompose ozone in accordance with the model:

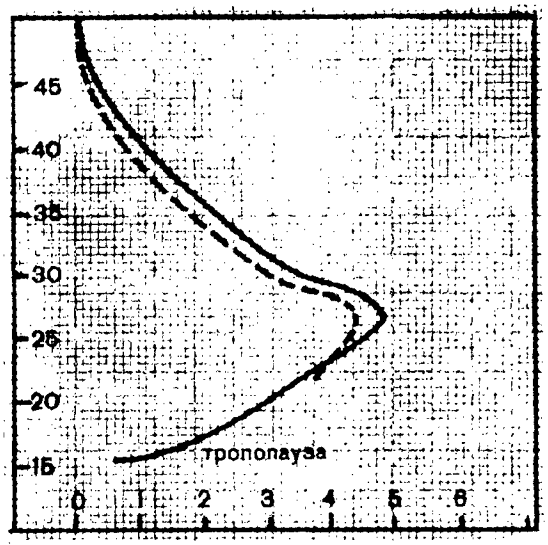
$$O + O_3 \rightarrow 2O_2.$$

A stationary (dependent on temperature and pressure) ozone concentration is established due to the simultaneous formation and decomposition of ozone in the atmosphere. Since radiation with an absorption maximum at 2550 A does not penetrate below an altitude of about 20 km, the most favorable altitudes for the existence of a stationary ozone layer are 20-30 km.

One of the factors which could impair the equilibrium of the ozone layer is the atmospheric accumulation of freons (dichlorodifluoromethanes).

Dichlorofluoromethanes (CF_xCl_x), especially CF_2Cl_2 (freon-12) and $CFCl_3$ (freon-11) have low boiling points (-30° and +24° respectively), are nonpoisonous and are chemically inert. Therefore they are coming into wider and wider use: freon-12 as a coolant in refrigerators, both freons -- in foam fire extinguishers as the raw material for producing fluorolephins, as anasthetics and on a very large scale, especially abroad, as propellants in aerosol cans.

During 1974-1975 specialists at the University of California M. Molin and F. Rowland published the results of theoretical investigations made using a one-dimensional, linear model on an electronic computer. (By the term "one-dimensional model" is meant that all the computations were made on the assumption of movement of a flow of dichlorodifluoromethanes from the earth's surface only in a vertical direction.) On the basis of these investigations they predicted that the accumulation of dichlorodifluoromethanes observed during recent years in the atmosphere can be a cause of the destruction of the earth's ozone shield and thereby in the immediate future could cause a whole series of problems threatening the earth's population.



Computed (solid curve) and experimental (dashed curve) vertical profiles of the concentration of ozone in the atmosphere (22°N, 158°W). Along y-axis -- altitude (km), along x-axis -- ozone concentration (10^{12} mol·cm^{-3}). From P. Crutzen, 1975. Annotation in figure: tropopause

These communications alarmed public opinion in the United States because there the total production of freons 11 and 12 in 1974 attained 2.3 million tons and had increased by 54% in comparison with 1972 and the production of aerosol cans in 1975 was 2 billion 350 million units against a world production of 6 billion. With respect to this enormous quantity of freons, 50% is used in aerosol cans, 28% in refrigerator equipment, and the rest for other purposes. In November 1974 the United States Congress had to consider the problem of banning the production of dichlorodifluoromethanes and in June 1975 a proposal was introduced to ban the sale of aerosol cans for household insecticides, lacquers for furniture, use for the hair and deodorants, etc., in which freons are used as propellants. Legislation on this matter has not yet been passed for the entire country, but only for the state of Oregon. At the present time debates are going on between representatives of academic institutions, carrying out additional investigations for backing up such a ban and the representatives of companies producing dichlorodifluoromethanes and aerosol cans. The firms are carrying out additional investigations for demonstrating the relative harmlessness of accumulation of dichlorodifluoromethanes in the atmosphere in comparison with other potential sources of particles capable of destruction of atmospheric ozone. It has been established that due to the increasing use of freons their concentration in the atmosphere is increasing from year to year by 10% and this increase is proportional to the use of freons in aerosol cans. In 1975 the mean concentration of freon-12 in the troposphere was 130 parts per trillion and the concentration of freon-11 was 100 parts per trillion and the same for carbon tetrachloride and trichloroethane. Speaking figuratively, this is four drops in 380 liters, but in absolute units these are not such small values if it is taken into account that in 1974 0.5 million

tons of the produced 2.3 million tons of freons were actually ejected into the troposphere. But due to the extremely small solubility in water, dichlorodifluoromethanes are not eliminated from the troposphere by rain and in addition, they are so inert relative to air and oxygen that their presence in the troposphere can serve as an indicator of movement of atmospheric masses. Moreover (we ourselves have repeatedly confirmed this), dichlorodifluoromethanes are inert to gaseous, liquid and solid ozone.

Then what is the threat of accumulation of freons in the atmosphere for the ozone layer?

It is postulated that upon diffusing into the stratosphere the freon molecules are subjected to the photolytic effect of solar radiation (for the most part in the UV region 1840-2250 A, which is not absorbed by oxygen and ozone molecules), as a result of which they become sources of chlorine atoms:

$$CFCl_3 + h\nu \rightarrow CFCl_2 + Cl;$$
$$CF_2Cl_2 + h\nu \rightarrow CF_2Cl + Cl.$$

This photolytic dissociation does not occur in the troposphere and the maximum value of its coefficient, according to estimates, should be observed precisely at that altitude in the atmosphere where the ozone concentration is maximum.

The flux of dichlorodifluoromethanes into the stratosphere is proportional to their concentration in the troposphere. If the production of dichlorodifluoromethanes continues at the same rates as at the present time, the concentration of freons in the troposphere, now equal to 10^{-10}, will increase each three years by the same value and after a definite time will attain a state of equilibrium, increasing the fraction of chlorine atoms in the stratosphere. The danger of accumulation of chlorine atoms is that they catalyze the breakdown of ozone in the following way:

$$\begin{array}{c} Cl + O_3 \rightarrow ClO + O_2, \\ \underline{ClO + O \rightarrow Cl + O_2.} \\ O_3 + O \rightarrow O_2 + O_2. \end{array}$$

Computations show that at the present time the breakdown of ozone in the stratosphere as a result of this catalysis should not be great (less than 1%), but since the concentration of freons in the atmosphere is increasing by 10% per year, during the period between 1975 and 1990 the rate of decomposition of ozone by chlorine atoms will already be appreciable. If the ejection of freons into the atmosphere ceases in 1978, the ozone concentration in the ozone layer will decrease up to 1990 only by 3%, which will not exert a great influence on terrestrial life. But if the entry of freons into the atmosphere does not cease until 1995, then in 2000 the ozone concentration will decrease by 10% and will remain at that level for a long time, causing considerable harm to everything living. If the entry of freons is not stopped, in 2000 the ozone concentration in the ozone layer surrounding the earth will drop by 20%[1]. These figures become particularly striking if

it is taken into account that a decrease in ozone content in the ozone shield by 16% can cause a worldwide increase in the number of cases of skin cancer[2].

It should be noted that the evaluation of the influence of chlorine atoms during the photodissociation of freons on the breakdown of atmospheric ozone was carried out taking into account the splitting off only of the first chlorine atom from each of the dichlorodifluoromethanes taken into account. In actuality, all four halogen atoms (two fluorine atoms and two chlorine atoms in the case of freon-12 and one fluorine atom and three chlorine atoms in the case of freon-11) should split off. But even with the nonparticipation of the fluorine atoms in the process of catalytic breakdown of ozone the predicted influence of freons on the earth's ozone layer is evidently understated because the calculations do not take into account the chlorine atoms which can enter the stratosphere from other sources.

Thus, the danger for the stratospheric ozone layer is not freons in themselves, but chlorine atoms.

Then the following questions arise: are freons the principal potential sources of chlorine atoms in the stratosphere? Are there not present in the stratosphere other molecules or radicals which are more competitive in the reactions with chlorine atoms than ozone? Does the stratosphere contain other molecules or radicals more capable of reaction with respect to ozone and oxygen atoms than chlorine and its oxides?

With respect to the first question it should be noted that in addition to freons, possible sources of stratospheric contamination with chlorine atoms could be the HCl of volcanic origin and a number of dichlorodifluoromethanes and chloroethanes, the products of man's economic activity -- carbon tetrachloride, chloroform, methyl chloride, ethylene dichloride, tetrachloroethane, etc., as well as the chlorine forming during the decomposition of rocket fuel NH_4ClO_4.

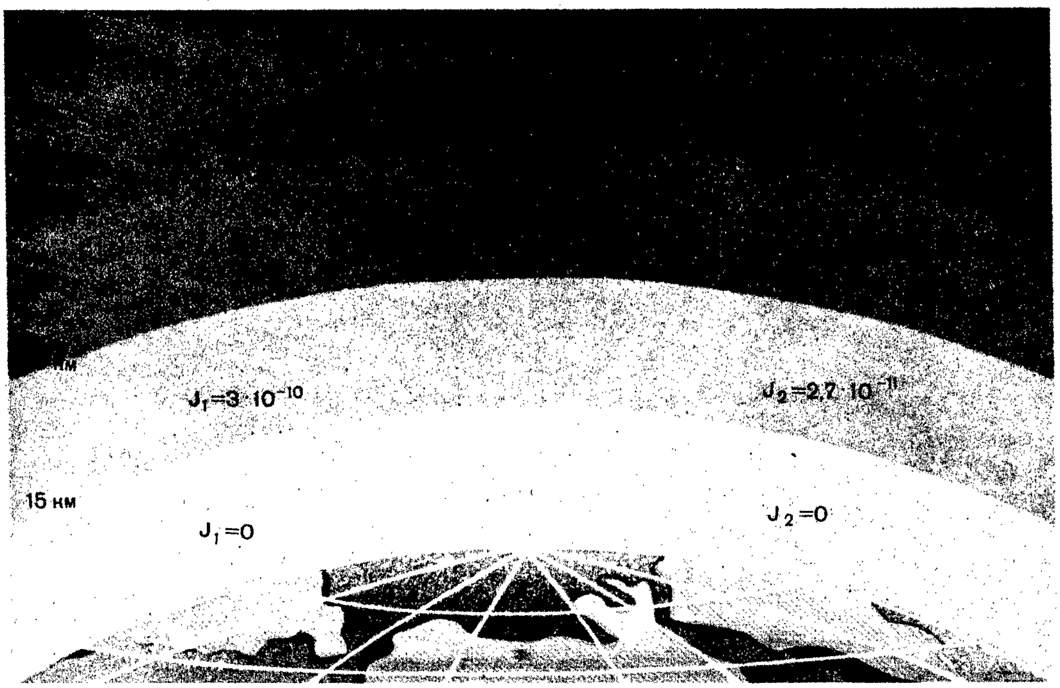
HCl can form chlorine in the reactions:

$$HCl + h\nu \rightarrow H + Cl \; (\lambda < 24 \text{ нм}),$$
$$HCl + O \rightarrow OH + Cl;$$
$$HCl + OH \rightarrow H_2O + Cl$$

(HM = nm)

But since HCl is a readily soluble compound and readily capable of reaction, only 4% of it reaches the stratosphere and accordingly it exerts little influence on the ozone balance in comparison with the chlorine originating from freons. The very same thing could be said with respect to anthropogenic chloromethanes and chloroethanes, among which only carbon tetrachloride could be visualized as a danger for stratospheric ozone. The others are washed out by the rain, or more than freons, are subjected to decomposition due to the double bond C = C. True, in the opinion of G. Lovelock (Great

Britain), the accumulation of carbon tetrachloride in the stratosphere is of the same potential danger for the ozone layer as the accumulation of freons. Like the latter, it is capable of persisting for a long time in the atmosphere (34-40 years) and the rate of its photodissociation is greater than for freon-11. But since the greater part of the produced carbon tetrachloride goes for the production of freons, the principal danger is nevertheless in the excessive increase in the production of freons in comparison with other halogen-substituted hydrocarbons. The ratio of the freons now accumulated in the troposphere to the remaining chlorine-derivative hydrocarbons is already greater than unity.



Estimated values (sec^{-1}) of coefficients of photodissociation -- J_1 for freon-11 and J_2 for freon-12. From R. I. Cucerone, R. S. Stolarsky and S. Walters, 1975. The maximum value of the photodissociation coefficients (and this means the maximum concentration of chlorine atoms regenerated by freons) is expected at that altitude in the atmosphere where the earth's ozone layer is concentrated.

In order to answer the second question, as to whether in the stratosphere there are other molecules or radicals more capable of reaction relative to chlorine atoms than ozone it is necessary to consider the reaction products of these radicals and molecules with chlorine atoms. The most commonly observed compounds present in the stratosphere, reacting with chlorine, yield HCl, which under the influence of radiations or oxygen atoms and OH

radicals in turn generate chlorine or ClO radicals. The latter, also forming under the influence of nitrous and nitric oxides (also present in the stratosphere) not only participate in the ozone decay cycle, but can also enter into reaction with nitric oxide and nitrogen dioxide with the formation of atoms of chlorine and chlorine nitrate respectively:

$$ClO + NO \rightarrow Cl + NO_2;$$
$$ClO + NO_2 \rightarrow ClNO_3.$$

The considered reactions do not impede the catalytic cycle Cl - ClO, since their rates under stratospheric conditions are less than the rate of the reaction of chlorine with ozone.

As stated by F. Rowland (United States) in one of his reports in May 1976, the destruction of ozone in the cycle Cl - ClO could be represented only as:

$$ClO + NO_2 \rightarrow ClNO_3.$$

The formation of chlorine nitrate could reduce by 50% the earlier cited data on destruction of the ozone layer.

With respect to the question as to whether in the stratosphere at the altitude where the ozone concentration is maximum there are other molecules and radicals more capable of reaction relative to ozone and oxygen atoms than chlorine and its oxides for the time being can be answered negatively.

However, it must be emphasized once again that the proposed models of the destruction of the ozone shield surrounding the earth by chlorine and its oxides are probable and actually can cause a restlessness of public opinion, but it should be remembered that as of today they have not been confirmed by direct observations in the stratosphere itself.

Accordingly, in 1975 specialists in the United States, Great Britain and Canada initiated intensive investigations. Their purpose was a systematic determination of the concentration of compounds of chlorine, fluorine, atoms of chlorine and ClO radicals in the atmosphere, study of the interaction of chlorine and ozone atoms, development of methods for the direct determination of ClO radicals and chlorine atoms in the atmosphere.

Reactions of Chlorine Atoms with Some Hydrogen and Nitrogen Compounds in the Stratosphere

$$CH_4 + Cl \rightarrow HCl + CH_3$$
$$H_2 + Cl \rightarrow HCl + H$$
$$HO_2 + Cl \rightarrow HCl + O_2$$
$$OH + Cl \rightarrow HCl + O$$
$$H_2O_2 + Cl \rightarrow HCl + HO_2$$
$$HNO_3 + Cl \rightarrow HCl + NO_3$$
$$N_2O + Cl \rightarrow ClO + N_2$$
$$NO + Cl \rightarrow NOCl$$
$$NO_2 + Cl \rightarrow ClO + NO$$

In addition, a committee of four persons -- Lovelock (Great Britain), Pitts, Taylor (United States) and Sandorfi (Canada) was assigned the task of formulating a research program for the next three years. In formulating the program the emphasis was on the processes transpiring in the stratosphere. The program consists of the following points: determination of the concentrations and lifetimes of different chloro- and chlorofluorocarbons in the lower layers of the atmosphere for establishing more precisely specifically which of these compounds are capable of migrating in the stratosphere and in what quantity; evaluation of the possible natural mechanisms favoring the elimination of compounds containing chlorine near the earth's surface; determination of the possible reactions of chlorofluorocarbons and free chlorine with other compounds in the atmosphere capable of reaction; study of the greatest possible number of stable compounds containing chlorine and their reactions; development of an analytical method for a quantitative determination of the concentration of the ClO radical in the stratosphere.

Some of these experiments are already being conducted, work is being done on others and methods are being correlated. NASA and the NOAA are active participants in these investigations. These organizations are planning to carry out an extensive research program in the stratosphere using the latest measurement apparatus carried aboard aircraft, rockets, balloons and artificial earth satellites. For example, for checking the presence of chlorine atoms in the stratosphere at altitudes up to 80.5 km NASA makes use of the "OAO-3" satellite of the Copernicus type which was launched in 1975. It will carry out measurements each six months over a period of several years. For spectroscopic determination of the ozone concentration the "Nimbus-6" and "Explorer-E" satellites were launched in this same year. Direct measurements in the stratosphere carried out by balloons in 1975 by NOAA and the United States National Atmospheric Research Center confirmed that at an altitude of 19-22 km the concentration of freons 11 and 12 corresponds to the theoretically computed level. In addition, it was established that freons 11 and 12 diffuse in the stratosphere without experiencing great losses in the lower layers of the atmosphere. The determinations were made by the gas chromatography method.

Thus, it has been convincingly demonstrated that the atoms of chlorine and its oxides cause a catalytic decomposition of ozone. It is a reliably established fact that there is an accumulation of freons in the troposphere with their subsequent migration into the stratosphere without changes in composition and concentration.

The participation of freons in the generation of chlorine atoms and the ClO radical under stratospheric conditions is today only a hypothesis because their photodissociation for the time being has been observed only at room temperature. But even if this hypothesis is experimentally confirmed, it is impossible to regard the reactions of chlorine atoms and the ClO radical with ozone to be isolated from the entire complex of other possible

chemical and photochemical reactions transpiring in the stratosphere. And the latter can be so complex that they will unresolvable for any one-dimensional linear model. If the hypothesis is true, the breakdown of the earth's ozone layer by freons 11 and 12 is approximately 1% and does not constitute a danger for mankind. However, if the hypothesis is not refuted in the next two years it will be necessary to conclude an international agreement providing for the restriction of use or even banning of production of these chlorofluorocarbons because otherwise the situation will deteriorate considerably during the next decade.

FOOTNOTES

1. R. I. Cucerone, R. S. Stolarsky, S. Walters, SCIENCE, Vol 185, No 4125, 1974, p 1165; 1975, Vol 188, No 4186, p 378.

2. P. Crutzen, AMBIO, 1975, Vol 3(6), p 201; SCIENCE, 1975, Vol 189, p 457; Mersova, N. A., KHIMICHESKAYA PROMYSHLENNOST' ZA RUBEZHOM, 1975, No 11, pp 72-76.

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